Jetties for Improving Estuaries.[1]

By Lewis M. Haupt, A.M., C.E.,

Professor of Civil Engineering, University of Pennsylvania.

For centuries the efforts of engineers have been directed towards reducing the heights of the bars which obstruct the entrances to harbors or rivers on alluvial coast.

They have attempted to apply the concentrated ebb stream to a limited portion of the bar by means of jetties, reaching at times above high water, in other cases to half tide, and again being entirely or partially submerged. As the resources of the profession appear to be limited to such constructions aided by dredging, and as the practice seems to be to follow the precedents furnished by experience, it will be instructive to note the results of these structures upon the entrancee where deeper water is desired.

In considering the results produced it will be found convenient to classify the structures, according to their conditions of exposure, into three groupes :

(1) Where there are tidal fluctuations of considerable magnitude, with but small interior tidal reservoirs and little or no fresh water drainage.

(2) Where the tidal oscillations are small and the land discharge large ; and

(3) Where there is a considerable fresh water volume débouching into a tideless sea or lake.

In the first class, where the attempt has been made to improve the channel by scour between jetties, the works have in general proven unsuccessful, as they have invariably resulted in advancing the general shore land, and in pushing the bar further to sea without material increase of depth over its crest. This

[1] Reprinted from the *Journal of the Franklin Institute*, April, 1888.

inherent defect has been partially overcome by constructing large sluicing reservoirs contiguous to the channel and by the frequent recourse to dredging.

In justification of such works for tidal estuaries in this country, frequent reference has been made to the success of the jetties at the Sulina mouth of the Danube; to the various harbors on our great lakes; to Swinemunde, on the Baltic, and to the South Pass, on the Gulf of Mexico, but the instances are unfortunate for the reason that the seas are tideless or nearly so, and the volume of fresh water discharge is relatively large as compared with the tidal prism, thus placing them all in the second or third group.

The only case in this class that has come under our observation which has approximated to a successful result, is that at the mouth of the Liffey, at Dublin Harbor, where the improvement is largely due to a gap of 600 feet left in the north wall at its shore end, through which the ingress of the flood tide is facilitated. To this extent it confirms the theory and plans which are suggested herein for the difficulties encountered in such cases.

Extracts from a paper read May 20, 1879, by John Purser Griffith, Assoc. M. Inst., C.E., on "The Improvement of the Bar of Dublin Harbor by Artificial Scour:"

"Mr. Giles recommended that an opening should be left at the shore end of the proposed wall 600 feet wide, to allow of a free passage for the tidal waters north of the Green or Bull Island, as the sand island on the North Bull was called. This opening had been proposed by Captain Corneille in 1802; but at that time the Directors General of Inland Navigation feared that the tide flowing through this opening would carry sand from the North Bull into the harbor, and that the injury thus done to the port might more than counterbalance any advantage to be gained by the opening.

"In 1835, Sir William Cubitt reported upon the state of the harbor. Referring to the improvement of the bar, he says: 'The great increase of depth and improved channel over the bar I attribute entirely to the erection of the Great North Wall, a measure founded upon sound principles and carried into effect in a manner well calculated to effect the desired purpose, viz., that of checking the influx of sand upon the flood tide from the North Bull into the harbor and giving an increased impetus at the ebb tide by means of narrowing the stream, and confining it in a direction suitable for keeping open the best channel, the effect of which is already shown by an increased depth of five feet over the east bar since the erection of the Great North Wall.'"

Captain Washington, in his report, written in 1845, on the harbor of Dub-

lin, as one of the Tidal Harbor Commissioners, referred to the Great North Wall as follows:

"The propriety of this measure, which involved so heavy an expenditure, has been a subject much controverted amongst persons connected with the port, but it is believed that there is now but one opinion as to its beneficial effects, and that the plan evinced both good judgment and skill."

There are few, if any, cases of a bar and entrance channel to any harbor being increased in depth like that of Dublin, viz.: about seven feet in thirty years, and great credit is due those who designed, as well as those who executed works which have achieved so important a result.

The improvement of Dublin Harbor entrance ranks second to none. There is no other example, so far as the author is aware, of the construction of an artificial estuary for scouring purposes which has proved so successful

DISCUSSION.

Mr. Abernethy, Vice-President, said he thought attention should be directed to the construction of works which would tend to increase the tidal volume, and at the same time to prolong the action of the outgoing currents from the period of half ebb towards low water.

Mr. Bergeron stated it was very difficult, almost impossible, to dredge sand bars in an open sea.

Mr. Vernon-Harcourt, that to diminish the tidal capacity within a harbor was the worst thing that could possibly be done.

Mr. Griffith said: "Prior to the construction of the Great North Wall the ebb of a spring tide attained a velocity of one and one-fourth miles per hour across the bar, while at present it reached nearly three and one-fourth miles, showing an increase of about two miles per hour." He did not believe that very high velocities were efficient. Several instances might be named in which high velocities were attained, and yet the scour was a failure.

Mr. Stoney thought that though there might be some doubt as to the authorship of the Great North Wall, there could be none as to its complete success.

In the application of the jetty system to the alluvial harbors of the Atlantic Gulf Coast, an effort has been made to compromise the conflicting requirements of *free ingress to flood* and concentration of ebb by building submerged structures of brush mattresses, with a rip-rap covering. These jetties subsided rapidly, and in some instances shrank over fifty per cent. of their original volume, making them cost more than stone. Their effect in an incomplete state has been to push the bar seaward and to induce a scour along their edges, requiring protection by spur dykes without at the same time materially increasing the depths over the bar.

For the ports on the Gulf, the question is one of vital importance. The State of Texas alone embraces 237,504 square

miles, yet the best harbor, which is found at Galveston, has but thirteen feet of water and a mean rise of tide of only 1.1 feet. Whatever plan gives greatest promise of a successful issue should be the one applied, and it must be based upon a knowledge of the resultant forces operating at that entrance as revealed by a comparative study of its physical hydrography.

Without giving a critical, detailed statement of these conditions, a succinct history of the changes will indicate the main points to be considered in designing a structure applicable to this site.

HISTORY.

The U. S. Coast Survey of 1867 revealed a remarkable progression of the shore-line and islands to the southwestward, and a shoaling of over three feet on the inner bar. To resist these changes, the U. S. Engineers began the collection of data by surveys in 1868, and upon these have submitted several plans for accomplishing the desired object. McAllister's hope was in dredging; Howell's in parallel jetties of gabions, which are now beneath the sands; Mansfield and the Boards of Engineers trusted to submerged jetties, one of which was partially built; Eads believed that high convergent jetties would produce the required result, and in this view the permanent Board of Engineers has at length acquiesced as the only proposed plan that has not been tried. So a score of years has passed and there is virtually no better water, yet in the Report of January 21, 1886, the Board of Engineers says: "Deeper water on the bar is needed, and the question to be considered is, how that deep water can be obtained. The methods are two: (1) by dredging alone; (2) by using tidal scour between jetties, aided, if necessary, by jetties. As to the first method, it has already been tried unsuccessfully." * * * "The second method would include the obtaining of a deep channel way to be protected by jetties from the deteriorating effect of wave action, and from the influx of sand, and the maintenance of that channel way by the aid of the tidal scour, supplemented, if found necessary, by dredging. The jetties should be so placed as to secure the greatest tidal scour practicable, without seriously injuring the interior harbor, and without greatly endangering the safety of the jetties against undermining or of Galveston Island from overflow in great storms. The greatest scouring effects will be

obtained, and the greatest security against undermining by making the jetties tight and by raising them above high water." * * * * "Cost of jetties complete to thirty-foot curve, $7,000,000, their aggregate lengths being nearly 54,000 feet. This estimate supposes that the money is freely supplied."

UNCERTAINTY AS TO RESULTS.

When so large an amount is involved (although it is small as a measure of the interests at stake) we should expect to find a reasonable amount of confidence as to the results to be obtained. It will be seen that the project is dependent upon tidal scour, and that this can only be obtained by concentration of the *ebb* currents upon some point of the bar. To effect such concentration the flood tide must be freely admitted to the inner bay, so it may be "filled at every influx of the tidal wave," for if the flood is diminished in volume, the ebb will be likewise reduced, and if a part, say one-half, of the gorge between Fort Point and Bolivar Island were filled up, it would restrict the flood in nearly the same ratio. High jetties would produce such an effect by cutting off the incoming tide from the funnel-shaped entrance of the gorge, and practically transferring the latter to the crest of the bar where the velocities are much less. That such a result is anticipated by the Board appears from their report just referred to, where in discussing the

WIDTH BETWEEN JETTIES,

they say: "Such a jettied channel offers more resistance to inflow than does the present entrance; reduces the present tidal prism about one-third; allows the bay to fill more slowly than the present entrance does, and hence gives greater differences of level than that given by the present entrance;" and they add: "Diminishing the interval between the jetties from 7,000 to 3,500 feet, changes the difference of level between the bay and gulf but slightly. Through the opening of the same depth and double width, about twice as much water will flow in and out, but as it flows through a double cross-section its velocity is nearly the same, * * and the depth will be nearly the same." Again, on page 18, the Board says, "the jetties will diminish the freedom of inflow at Galveston."

Another Board, composed in part of the same officers, reported with reference to the jetties at Sabine Pass, in these

words: "Now, if jetties are built from the shore, 1,800 feet apart, as proposed, across the bar to deep water, the pass is virtually prolonged three and one-half miles, and its mouth transferred to the same distance seaward. The funnel-shape of the entrance way will be lost, and the surface slope of the channel of this elongated pass will be diminished, both of which changes will decrease the tidal flow."

From these extracts it would appear that the authorites are agreed that concentration of ebb or tidal scour can only be obtained at the expense of the flood volume, and that the successful application of jetties depends upon a proper adjustment of the area and length of the channel between the jetties to the tidal volume of the inner bay.

GREAT WIDTH BETWEEN JETTIES.

Upon this point Captain James B. Eads says: "The slope (producing scour) results from the difference of level between the surfaces of the gulf and the bay. Any one can see that the more freely the water can flow from one to the other, the less difference will there be between the heights of their respective surfaces, and consequently the less will be slope of surface through the channel between them, and the less will be the current velocity. This is certainly the very opposite of what we *must have* to produce deepening. Hence, it is evident that *large openings* and a freer communication with the bay through them, and over low, submerged jetties, are precisely what we do not want."

Hence, while the doctors disagree, the one condemning narrow, the other wide passes, we may leave them to their opinions and read the lessons of experience from

THE BOOK OF NATURE.

When large inner bodies of water are connected with the ocean by small inlets, it becomes impossible for the inflowing tide to fill them to the level of the ocean during the time of the rise or fall.

A small volume may pass in when the outer level is above the inner, and *vice versa*, but the general level of the water in the bay or sound will not be sensibly affected, and it will stand at about the height of mean tide. The flood will then begin to flow in at half tide, and will have its maximum velocity at

"high-water-stand," and the ebb will occur between mid-tide and low-water, but as the inlet is small and the inner prism large, the currents will be too feeble to produce marked effects. This action is very perceptible at Albemarle and Pamlico Sounds, where, according to the United States Coast Survey Report of 1862, page 45, it is said, "the basin being nearly tideless, has its surface lying at about the mean level of the sea—that is, at the half-tide plane—and it is upon this plane that the currents of the inlet must take the initiative. Moreover, the maximum velocities must occur when the greatest contrasts of height between the ocean and the sound obtain; that is, at *high water* for *flood* and at *low water* for the *ebb*." The more the inlet is contracted, therefore, the lesser will be the tidal oscillation upon which the inner bay depends for its currents to maintain its channels. *Every construction on the bar becomes more or less of an obstruction to the tidal ingress*, and, consequently, neither high jetties nor submerged jetties will satisfy the conditions.

THE PROBLEM

is to discover a form and position of structure which will not seriously oppose the flood ingress, but which will utilize it for scouring over the bar; will cause it to deposit its load of sand outside the crest and not carry it into the channel; will concentrate a large portion of the ebb for effective work on the bar; will furnish every possible facility to vessels entering the port at all stages of weather, and prove at the same time an aid to navigation.

A solution which appears to fulfil all these fundamental conditions is herewith submitted by the author. It is based upon the fact, which is so frequently observed and referred to by the engineers in charge of improvements along the Gulf coast, that the resultant direction of all the forces acting year in and year out, is to the west and southwest, or, in other words, our coast line drift is rolling in that direction; and upon the further fact that the flood is the potent agent which lifts up the bars in front of our entrances, which the superficial and enfeebled ebb is unable to cut down. For example, the report on Pass Cavallo says: "Its history, like that of other entrances on this coast, showed a steady deterioration as a harbor and a constant shifting of the channel to the south and west. Yet the jetty is built on the *south* side of the channel, where it will catch the

sand and drop it in channel and fill it up as surely as a snow fence placed to the leeward of a cut will aid in filling the cut. It thus requires more work of the ebb, which must carry this sand out to the gulf beyond the end of the jetty, and thus extends the bar rapidly in that direction. Estimate for this pass, $1,039,280.

For Aransas Pass the report says: "And its history, like other entrances on this coast, shows a constant movement of its channel to the south, with progressive shoaling therein and enlargement of the Gulf Bar." Estimate $1,200,722.75. And the *south* jetty is again built to catch sand and obstruct the natural channel. Again at Brazos, where the estimated improvements were to cost $328,000, "approval was given to so much of the project as covered the construction of the *south* jetty," although "the harbor within was obstructed directly across the mouth of the pass by a bar in the *usual carved form*," [1] etc. At Sabine Pass, estimated to cost $3,177,606.50, the *west* jetty was built first and made a shoal on its east side, and in 1885 the crest of the bar had been moved seaward 1,900 feet, and it is said, "It is perhaps impossible to decide as to the amount of influence the work done has had upon the depth of water across the bar." And so at Galveston, the same experience is repeated and the same comments may be made as to effects produced.

WHAT IS TO BE DONE?

Evidently to barricade the sand by a break-water of a concave, curved form, so as to decompose the flood and precipitate its burden of sand outside the channel, and having a straight inshore flank to aid the flood in cutting a beach channel, short, deep and direct between bar and the shore, not by parallel or convergent jetties, but by a *single line of works having a total length of less than half that proposed for the high jetties, costing less than half the amount and producing much greater effects* in removing these serious obstructions to commerce. Thus nature will be aided in her efforts to build up an island or middle ground with a channel on either hand and a lee-way for all conditions of storm or tide.

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[1] The engineer in charge has recently reported with reference to this entrance that, "The work already done has disappeared without having any effect on the bar."